

## GROUNDWATER TRANSPORT OF RADIONUCLIDES FROM BURIED WASTE:

## A CASE STUDY AT OAK RIDGE NATIONAL LABORATORY\*

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ORNL SiteAbstract

Five burial grounds have been used in past operations at ORNL. Current burial ground studies show that burial ground 4 is the major contributor of  $^{90}\text{Sr}$  to the groundwater within the burial ground complex. Higher concentrations of  $^{90}\text{Sr}$  in the groundwater in the watershed in which burial ground 4 is located increase the amount of  $^{90}\text{Sr}$  in White Oak Creek, which drains the area and flows into the Clinch River. After burial of low-level waste in burial ground 4 was discontinued in 1959, the elevation of the water table in that burial ground increased. Then the area was used for disposal of uncontaminated fill. The fill increased the surface elevation and also increased the permeability of the surface soil. This raised the groundwater table because of the change in topography and the increased infiltration rate. The resulting saturated conditions and likely changes in soil chemistry increased the leaching rate of the buried waste. The increased leaching rate causes 1 to 2 curies of  $^{90}\text{Sr}$  to be transported from burial ground 4 each year.

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## Introduction

The purposes of this investigation, which is currently being conducted at ORNL, are to locate areas where radionuclides are transported by groundwater from buried waste, to estimate the quantity being transported, and to recommend engineering methods that will reduce radionuclide transport from problem areas. The study encompasses all waste disposal sites at ORNL and is funded by the Division of Waste Management and Transportation of the U. S. Atomic Energy Commission. The field studies were begun in the spring of 1973, and only preliminary results are available. At this stage in the investigation, data pertaining to radionuclide transport have been compiled from only one solid waste burial ground. Thus, the following discussion pertains only to solid waste disposal area 4, and the engineering methods for the reduction of this radionuclide movement which are currently being conducted.

## Location and History

Solid waste disposal area 4 (burial ground 4) is situated in Melton Valley and is located 1/2 mile southwest of ORNL (Fig. 1). The burial ground was opened in February 1951 and was closed to routine burial in July 1959. The area encompasses approximately 23 acres, which were filled from the northeast to the southwest. Much of the site, especially the northeastern section, has been covered with uncontaminated fill that was taken from building excavations at ORNL. Disposal of uncontaminated fill at this site was discontinued in July 1973 based on preliminary findings of the current burial ground study. In some places as much as 20 ft of fill material overlies the buried waste.

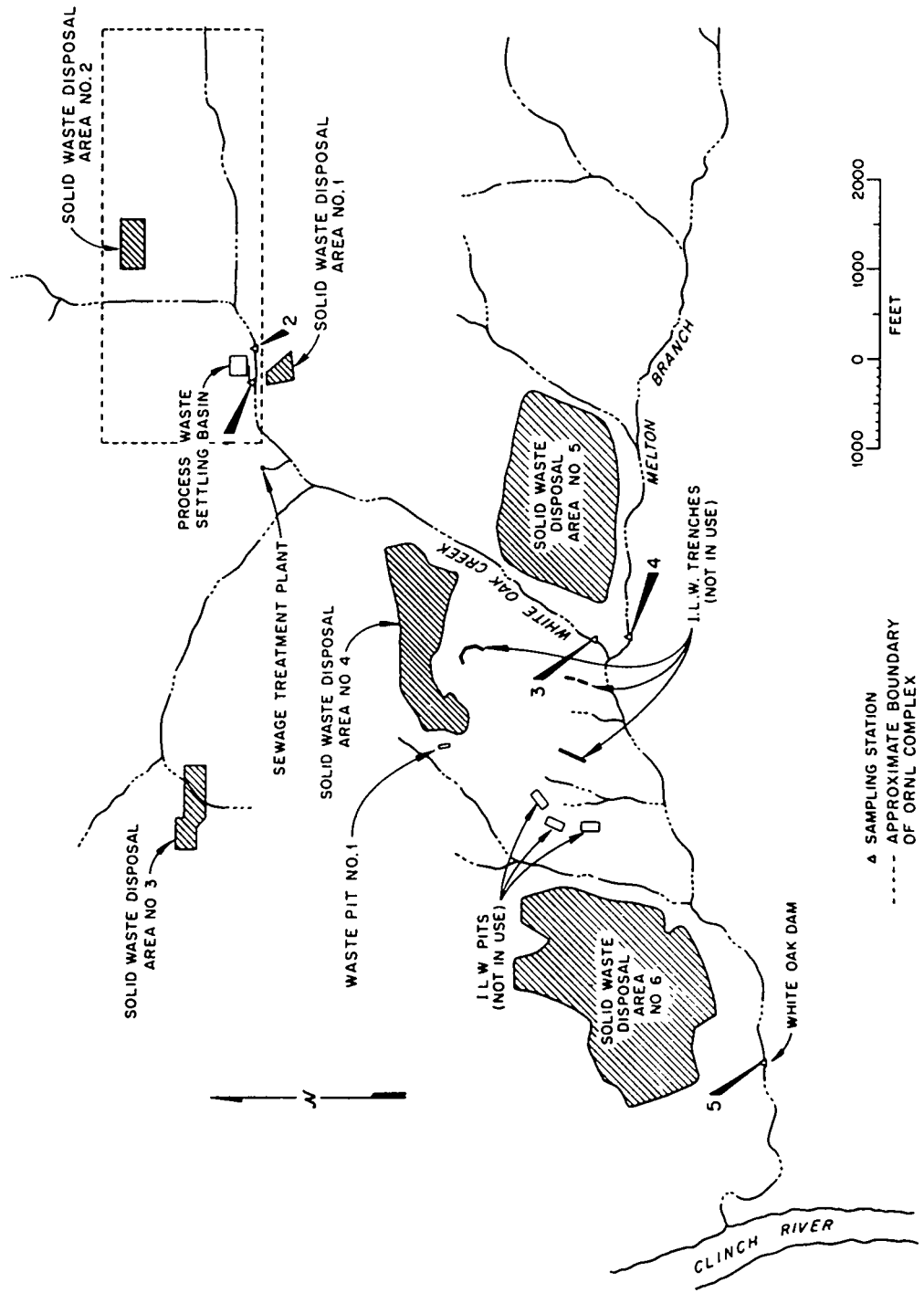


Fig. 1. Approximate Location of Waste Disposal Areas and Sampling Stations at ORNL.

The burial procedures consisted of excavating trenches into the weathered shale, dumping the contaminated waste into the excavation, and covering the trench with the original soil. In cases where the trench was known to contain alpha-contaminated waste, approximately 18 in. of concrete was placed over the trench. Approximately fifty auger holes, located in the northern part of the burial ground, were used for disposal of recoverable higher-level waste. These auger holes range from 1 to 2 feet in diameter and are lined with concrete. In addition, some special high-level waste was buried in individual stainless-steel containers.

The size and shape of the trenches are variable. They range from 50 to 400 ft in length, 8 to 30 ft in width, and 8 to 14 ft in depth. A wide variety of contaminated material was disposed of in burial ground 4. This material consisted of anything that was contaminated in normal laboratory or pilot plant operations, of which glassware, scrap metal, soil, lumber, contaminated chemicals and, in one case, a small building are a few examples. In many cases the waste was compacted using backhoes and bulldozers, causing many of the containers to rupture.

Little information is available about types, concentrations, locations, and quantities of radionuclides buried at this site. All records of the location and amount of waste buried prior to 1959 were accidentally destroyed by fire.

#### Geology and Hydrology

Burial ground 4 is underlain by the Conasauga shale, which varies

from red to gray, and is interbedded with thin limestone units. The formation consists mostly of maroon-to-brown, noncalcareous shale interbedded with gray, slightly calcareous shale and silty limestone. The shale is weathered to a depth of approximately 15 ft in the upper portion of the burial ground and to a depth of about 5 ft in areas near the stream. The Conasauga shale was selected for disposal of low-level waste because of its impermeability and relatively high adsorptive capacity for radionuclides.

All drainage from burial ground 4 is into White Oak Creek, which runs along the east edge of the burial ground. The groundwater table is essentially a subdued replica of the surface topography. Thus, the groundwater flows from areas of high elevation to areas of low elevation and ultimately discharges into White Oak Creek. The water table is relatively shallow and fluctuates at or near the land surface in low areas of the burial ground and attains a maximum depth of about 15 ft beneath higher elevations. Because of the high groundwater table, waste burial was limited to higher elevations during wet periods, while the low topography was utilized during the dry summer months (Lomenick and Cowser, 1961). The rate of groundwater movement is not known, however. This rate of movement should be much greater in the trenches than in the surrounding undisturbed shale.

#### Groundwater Monitoring

A groundwater monitoring system designed to monitor all of the groundwater flowing from burial ground 4 was installed along the east

end of the burial ground. The system consists of 37 shallow wells that were drilled during the summer of 1973 (Fig. 2). The wells are cased with 4-in.-diam aluminum casing and penetrate the flood plain of White Oak Creek to a maximum depth of 12 ft. They are on a 30-meter grid system for ease in well location. The grid system is also used for location of soil samples taken in the vicinity of the wells. Water from the monitoring system and from other wells installed during past burial ground studies is collected and analyzed periodically (Fig. 2).

#### Groundwater Contamination

Water samples collected from surface seeps and from wells contain primarily  $^{90}\text{Sr}$  with occasional small amounts of  $^{137}\text{Cs}$ . The  $^{137}\text{Cs}$  is strongly adsorbed by the Conasauga shale and is not readily transported from the buried waste by groundwater. The more mobile  $^{90}\text{Sr}$  is found in the groundwater in concentrations that range from 0.2 to 36.4 dpm/ml (Tables 1 and 2). Higher concentrations of  $^{90}\text{Sr}$  are found in some wells within the burial ground that are located nearer the buried waste. In some locations in the burial ground, trenches behave like tilted bathtubs. The trench fills with groundwater, which then spills over the lower end of the trench and appears in surface seeps. Here concentrations of  $^{90}\text{Sr}$  in excess of 400 dpm/ml have been measured.

The concentration of  $^{90}\text{Sr}$  found in the groundwater flowing from the east end of the burial ground is lower than the concentration found in the groundwater along the south side of the burial ground. For computational purposes, the entire drainage basin is divided into two parts,



Table 1. Concentration of  $^{90}\text{Sr}$  Flowing from Basin 1

Sample	Concentration December 1973 (dpm/ml)
Well, S212/W90	7.9
Surface, S214/W90	17.5
Well, S218/W90	15.4
Well, S227/W90	16.2
Surface, S228/W90	16.8
Well, S232/W90	2.3*
Average	14.8

\*Well excluded from the average because of dilution by uncontaminated groundwater flowing from the slope south of the burial ground.

Table 2. Concentration of  $^{90}\text{Sr}$  in Wells in the Lower Portion of Basin 2

Well	Concentration August 1973 (dpm/ml)	Concentration October 1973 (dpm/ml)	Average Concentration (dpm/ml)
N30/E90	0.2		0.2*
N30/E105	1.3	1.9	1.6*
N30/E135		1.3	1.3*
N0/E95		0.2	0.2*
N0/E106	1.2	1.3	1.3*
S16.6/E97.8		1.8	1.8
S30/E100		6.9	6.9
S30/E109	10.4	8.5	9.5*
S30/E125		0.3	0.3*
S41/E95			
S60/E87	2.3	5.2	3.8*
S77/E73		11.5	11.5
S90/E40		14.1	14.1
S90/E60	6.8	3.9	5.3
S90/E75	3.5	4.7	4.1*
S96/E30		4.0	4.0
197	2.8	4.3	3.6
S120/W30	8.6		8.6
S120/E0	10.0	6.3	8.2
S120/E30	5.5	5.4	5.5*
S120/E60	7.6		7.6*
196		36.4	36.4
S150/W30	15.8	11.6	13.7
S150/E0	15.9	2.8	9.2
S150/E30	11.5	4.4	8.0*
S150/E60		5.1	5.1*
S180/W30	14.7	9.7	12.2
S180/E0	1.8	2.9	2.4*
S180/E13	2.0	1.6	1.8*
S210/W56		12.2	12.2
S210/W30	18.1	14.0	16.1
S210/W21	11.7	6.6	9.2*
195	13.6	10.4	12.0
Average			11.0

\*Wells excluded from the average because of dilution by groundwater flowing down the flood plain of White Oak Creek. Thus, wells near the creek channel are excluded from the average.

basin 1 and basin 2 (Fig. 3), based on the two different concentrations. The dashed line dividing the two basins crosses groundwater contours at a right angle. Thus, groundwater flowing from basin 1 has  $^{90}\text{Sr}$  concentrations shown in Table 1, and groundwater flowing from basin 2 has  $^{90}\text{Sr}$  concentrations shown in Table 2. The data shown in Table 1 were collected in December when precipitation was extremely high; as a result the  $^{90}\text{Sr}$  concentration in the groundwater may have been diluted by the heavy rains. Thus, the average concentration of groundwater flowing from basin 1 should be higher when more data are available. Data from wells near White Oak Creek were excluded from the average because of dilution by "uncontaminated" groundwater flowing downstream in the flood plain of the creek. The average concentration of  $^{90}\text{Sr}$  in the groundwater flowing from basin 1 is 14.8 dpm/ml, and the  $^{90}\text{Sr}$  concentration flowing from basin 2 is 11.0 dpm/ml. It is to be expected that these averages will be more accurate when more data are included.

#### Total Discharge of Strontium

A crude estimate of the quantity of  $^{90}\text{Sr}$  discharged annually from burial ground 4 can be made using precipitation and evapotranspiration data from the vicinity of the burial ground. These data for the years 1971 through 1973 are shown in Table 3 (Sheppard et al., 1973, and personal communication with G. S. Henderson of ORNL). The data were collected from Walker Branch Watershed, which is located approximately 3.5 miles to the northeast of burial ground 4. The topography and vegetation of Walker Branch are similar to those of basins 1 and 2 with

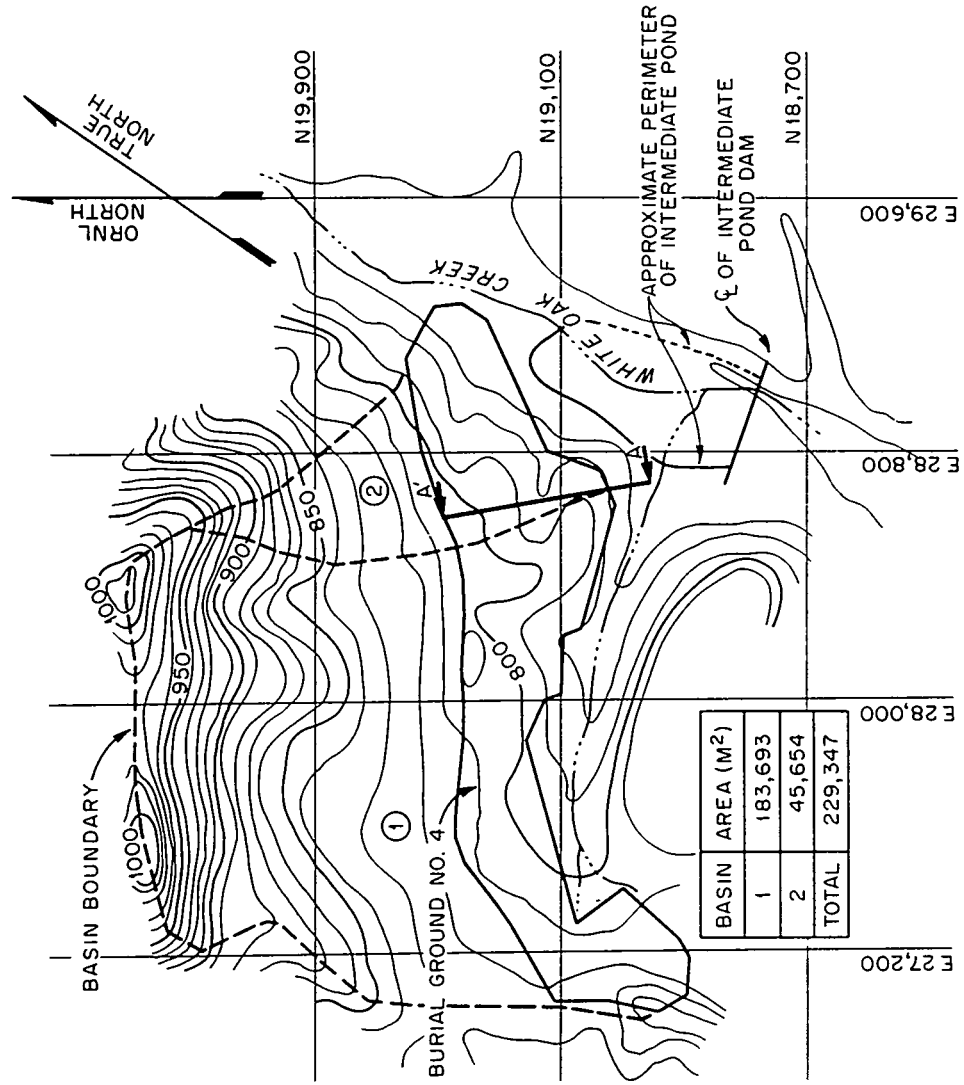


Fig. 3. Elevation Contours Prior to the Establishment of Burial Ground No. 4. The Dashed Line is the Perimeter of the Drainage Basin which is Divided into Parts 1 and 2.

Table 3. Annual Precipitation and Evapotranspiration Data  
from Walker Branch Watershed

Year	Precipitation (cm/year)	Evapotranspiration (cm/year)	Groundwater (cm/year)
1971	136.9	69.0	67.9
1972	157.6	67.9	89.7
1973	190.0	69.2	120.8

the exception that the burial ground itself is covered with grass rather than mixed hardwood forest. The surface runoff component in the Walker Branch Watershed is small and can be neglected. Surface runoff on the grassy surface of the burial ground is somewhat higher (Rogowski and Tamura, 1970), but for the following approximation it will be neglected.

When annual evapotranspiration is subtracted from annual precipitation, the result is the component of precipitation that becomes groundwater (Table 3). The groundwater component is then multiplied by the area of basin 1 and basin 2 (Fig. 3), using the appropriate conversion factor, to obtain the volumes of groundwater flowing through basins 1 and 2 each year. The results of these calculations for the years 1971 through 1973 are shown in Table 4. The volumes of groundwater flowing through basins 1 and 2 are then used with the average concentration of  $^{90}\text{Sr}$  at the outflow of the two basins (Tables 1 and 2) to calculate the annual discharge of  $^{90}\text{Sr}$  from each basin. The sum of the annual discharges from the two basins yields the total discharge of  $^{90}\text{Sr}$  from burial ground 4. This calculation shows that approximately 0.99, 1.31, and 1.77 Ci/year of  $^{90}\text{Sr}$  were discharged from burial ground 4 for the years 1971, 1972, and 1973, respectively. It should be noted here that the average concentration of  $^{90}\text{Sr}$  flowing from basins 1 and 2 was assumed to be the average concentration measured in 1973.

#### Stream Monitoring Data

The quantity of  $^{90}\text{Sr}$  discharged annually from burial ground 4 can be estimated from stream monitoring data. This estimation is obtained

Table 4. Calculated and Monitored Annual Discharge of  $^{90}\text{Sr}$  from Burial Ground 4

Year	Groundwater Flow (liter/year)		$^{90}\text{Sr}$ Discharge (Ci/year)		Total $^{90}\text{Sr}$ Discharge From B.G. #4 (Ci/year)	
	Basin 1	Basin 2	Basin 1	Basin 2	Calculated	Stream Monitoring
	A = 183,693 m <sup>2</sup>	A = 45,654 m <sup>2</sup>				
1971	124.7 x 10 <sup>6</sup>	31.0 x 10 <sup>6</sup>	0.83	0.16	0.99	1.19
1972	164.8 x 10 <sup>6</sup>	41.0 x 10 <sup>6</sup>	1.10	0.21	1.31	1.97
1973	221.9 x 10 <sup>6</sup>	55.2 x 10 <sup>6</sup>	1.49	0.28	1.77	2.19

by subtracting the annual release of  $^{90}\text{Sr}$  by ORNL (stations 1 and 2) from the annual discharge measured at monitoring station 3 (Fig. 1), which is located downstream from the burial ground. The results of this calculation for the years 1971 through 1973 are shown under stream monitoring in Table 4 (personal communication with G. J. Dixon, ORNL). The annual discharge calculated by this method would also contain any  $^{90}\text{Sr}$  released from burial ground 1, from burial ground 3, and from the west side of burial ground 5. Sampling in these areas shows that only negligible amounts of  $^{90}\text{Sr}$  are transported to White Oak Creek from these burial grounds. Comparison of the annual  $^{90}\text{Sr}$  discharge determined from stream monitoring with the calculated discharge shows reasonable agreement. The calculated values are 16% to 33% lower than the values obtained from stream monitoring, with the maximum difference occurring in 1972. Some of the 33% difference is attributed to a small leak in a waste transfer line, but the exact amount of the leak is unknown. A comparison of the estimated  $^{90}\text{Sr}$  release from burial ground 4 with the measured release to the Clinch River shows that approximately one-third of the release to the river comes from burial ground 4 (personal communication with G.J. Dixon, ORNL).

#### Interpretation of Results

The quantity of  $^{90}\text{Sr}$  transported from burial ground 4 is, in part, attributed to the relatively high groundwater table within the burial ground. The burial ground was located in an area where the water table was already high. However, the increased surface elevation due to disposal of uncontaminated fill has caused a rise in the water table. This

increased surface elevation has raised the water table elevation, because the water table generally reflects the surface topography in areas of high precipitation. Some of the increase in water table elevation is also brought about by an increased infiltration rate due to the permeability of unconsolidated fill material. A cross section located near the east end of the burial ground (Fig. 2) is shown in Fig. 4. This cross section shows the original land surface, the depth of fill, and the current groundwater table. It is interesting to note that the water table in all areas in the cross section is less than 9 ft below the original land surface (i.e., higher than the buried waste).

The high  $^{90}\text{Sr}$  discharge from burial ground 4 is caused by the rapid leaching of the buried waste under saturated conditions and, to some extent, by the chemical nature of the buried waste. Preliminary investigations of water quality in areas where high  $^{90}\text{Sr}$  contamination is found show abnormal water chemistry at these locations. This may indicate that chemicals buried with the contaminated waste have altered the adsorptive properties of the Conasauga shale to allow a more rapid transport of radionuclides. Detailed sampling and analyses to support this theory are currently being conducted.

### Conclusions

Preliminary results of radionuclide transport by groundwater from burial ground 4 show that 1.0 to 2.0 Ci of  $^{90}\text{Sr}$  are discharged into White Oak Creek annually. The amount of transport is dependent on precipitation and, to some extent, on the chemical nature of the waste

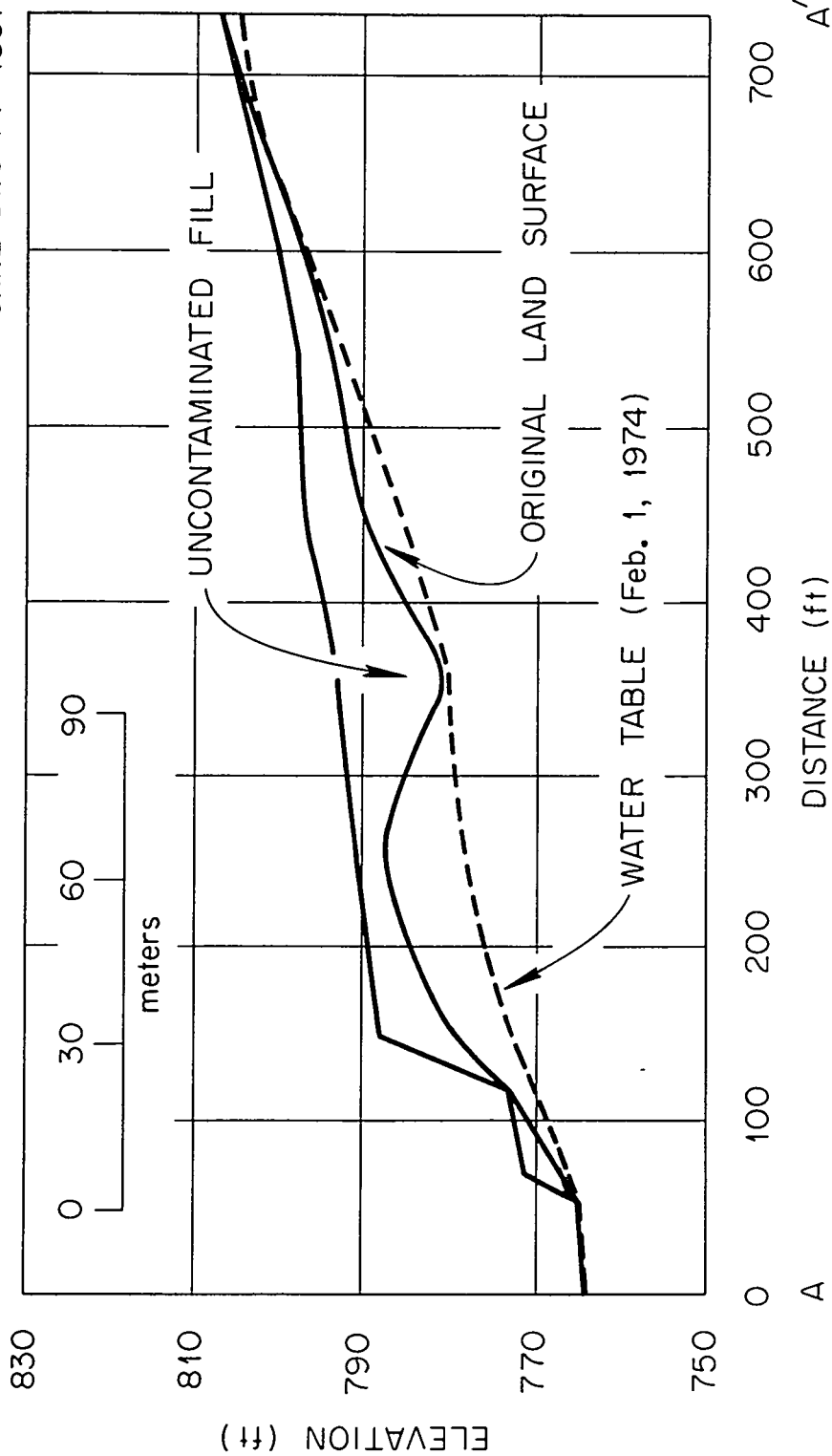


Fig. 4. Section A - A' Showing Present Land Surface, Original Land Surface, and Present Water Table.

itself. The quantity of  $^{90}\text{Sr}$  discharged from burial ground 4 is approximately one-third of the annual release from all ORNL operations. This represents a significant portion of the annual discharge from ORNL, and studies are currently being conducted to determine engineering methods that will reduce this amount.

References

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